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ELECTRON EXCITATION OF $H_2(v'')$ LEVELS TO YIELD VIBRATIONALLY EXCITED H_2 MOLECULES

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ABSTRACT

Electron excitation cross sections to produce vibrationally excited H_2 molecules are calculated for molecules initially in the first and second vibrational levels. The pattern of excitation cross sections as a function of final vibrational level v" differs from that found in previous calculations initiated from the ground vibrational level.

I. INTRODUCTION

The electron excitation of hydrogen molecules to form electronically excited states that in turn undergo radiative decay to the different vibrational levels of the ground electronic state provides for an excitation mechanism that is expected to dominate the operation of tandem high-density hydrogen-negative-ion discharges. These excitations provide for a vibrational population distribution that is more enhanced toward the excited vibrational levels, v">0, as the discharge electron density increases. The distributions presented to date however, have been calculated assuming that the initial excitation proceeds only from the lowest vibrational level, v"=0. As the portion of the population distribution in the excited vibrational levels increases to become a larger fraction of the total population, one can expect that the excitations that are initiated from these more highly populated excited levels will bear on the final distributions. Of particular interest is the possibility that these excitations will enhance the final distribution in the region of the spectrum that is principally responsible for negative in formation, $5 \leq v" \leq 11$. To explore this possibility calculations have been performed to evaluate the cross section for excitation to a final vibrational level v" starting from an initial level $\underline{v}"=1$ or $\underline{v}"=2$. These cross sections are indeed found to lead to an enhancement of the final-level cross sections in the range $5 \leq v" \leq 11$ compared to excitations initiated from the v"=0 level.

II. DISCUSSION OF CROSS SECTIONS

This paper is concerned with the excitation of a hydrogen molecule initially in a vibrational level $\underline{v}"$ of the $X^1\Sigma_g$ ground electronic state and excited by energetic electron collisions (E>20 eV) to yield vibrationally excited molecules, $H_2(v")$. These excitations proceed through all members of the singlet electronic spectrum. The subsequent radiative decay to the ground electronic state leaves a residual but vibrationally excited molecule, $H_2(v'')$. The principal singlet excitations proceed via the $B^1\Sigma_u$ and $C^1\Pi_u$ states; for these cases the overall reactions are

$$e + H_2(X^1\Sigma_g,\underline{v}'') \rightarrow e' + H_2(B^1\Sigma_u,C^1\Pi_u)$$
$$H_2(X^1\Sigma_g,v'')) + h\nu \ . \qquad (1)$$

The formalism for the effective cross section for the transition, $\underline{v}''\rightarrow v''$, (1) was derived previously and was evaluated[2] for the lowest vibrational level, $\underline{v}''=0$. These cross sections $\sigma(\underline{v}''=o;v'')$ are reproduced here in Fig. 1.

The cross sections for initial levels $\underline{v}''=1,2$ are shown in Figs. 2,3, respectively. Upon examining the $\sigma(\underline{v}''=1;v'')$ of Fig. 2 and comparing with the $\sigma(\underline{v}''=0;v'')$ of Fig 1 several differences are seen. In Fig. 2 the dominant cross section leads to $v''=1$ rather than $v''=0$. Also, the cluster of cross sections $\sigma(\underline{v}''=1;8,9,10,11)$ are now some considerable factor larger than for $v''=0$, while the $\sigma(\underline{v}''1;6,7)$ are reduced. The ordering of the σ's with v'' is now mixed and no longer falls off monotonically with increasing v'' as do those in Fig. 1.

Inspection of the $\sigma(\underline{v}''=2;v'')$ of Fig.3 shows that the largest cross section now occurs for $v''=2$. Here again, the $\sigma(v''=2;5,6,7,8,9,10)$ are enhanced relative to the corresponding σ's of Fig. 1. The pattern of maximum σ for $v''=\underline{v}''$ for all three cases is an interesting one and may have important consequences for negative ion production if this pattern persists into the higher portions of the spectrum.

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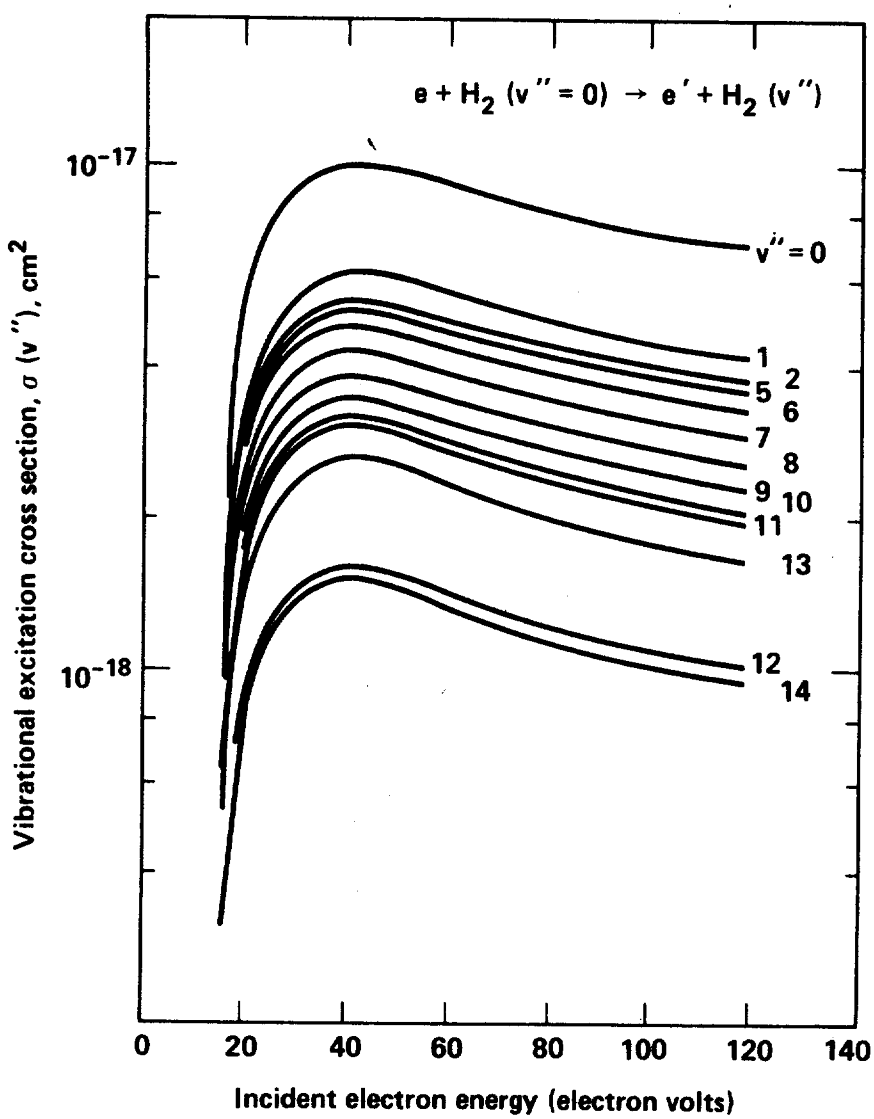

Fig. 1. Excitation cross section to level v" from initial level v"=0.

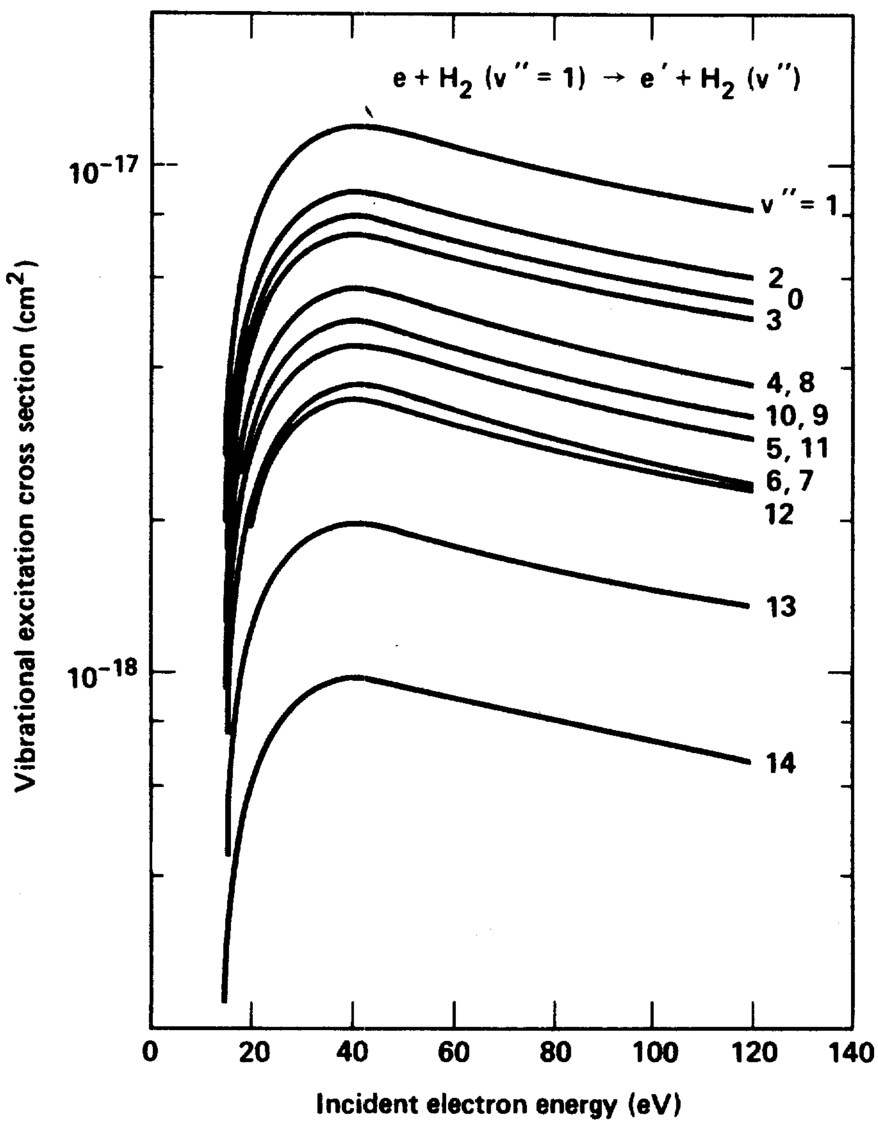

Fig. 2. Excitation cross section to level v" from initial level v"=1.

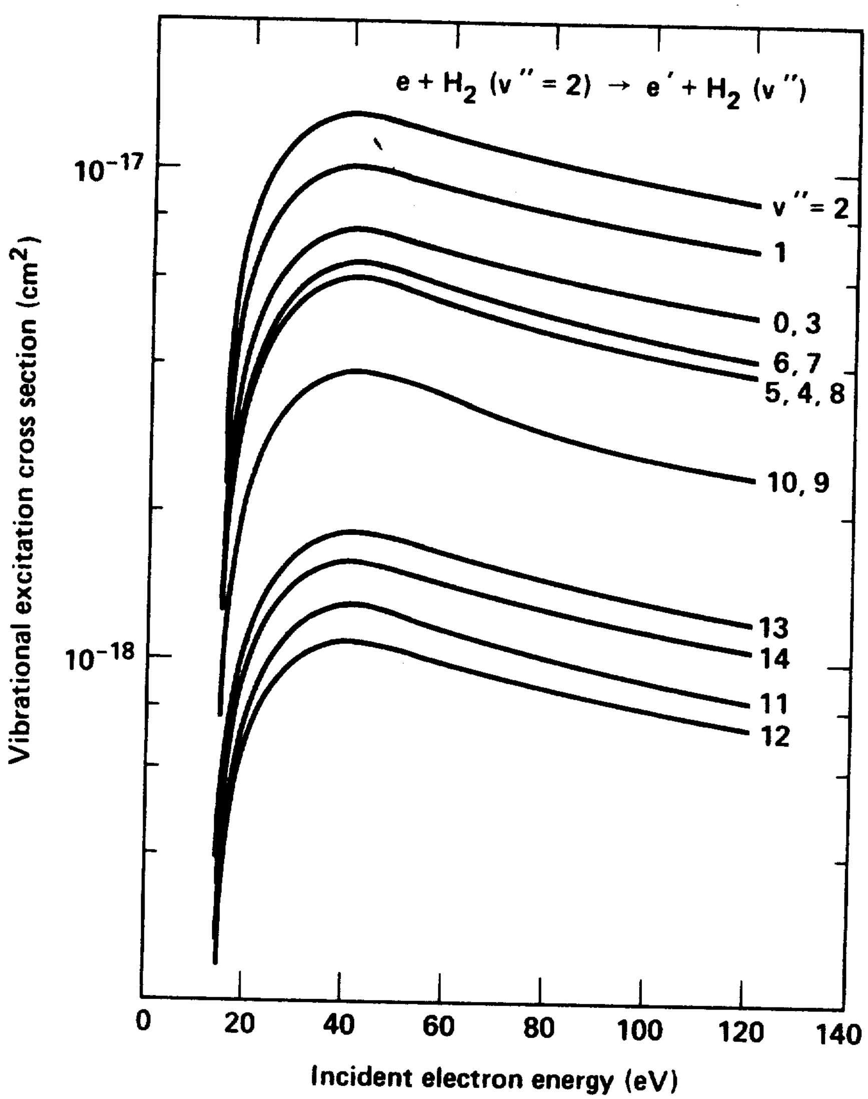

Fig. 3. Excitation cross section to level v" from initial level v"=2.